Lesson 2

Sustainability: The Rules of the Game

FOCUS

To introduce students to the science principles that mold life on earth.

CONCEPTS

- Keeping the Earth livable by practicing sustainability depends on working with natural laws and Earth system conditions rather than against them.
- There are four rules (natural laws based on scientific evidence) that underpin sustainability by describing the basic characteristics of Earth systems:
  1. Matter can change form (by interacting with heat or light energy), but cannot be created or destroyed.
  2. Matter and energy tend to disperse.
  3. The concentration and structure of matter determine how it can be used. It is this functionality that humans use up. Matter cannot disappear, but its functionality can. *Example:* In the water and ink experiment from Lesson 1, the water didn't disappear but when it was mixed with the ink, its usefulness did (it was no longer drinkable). Likewise, the materials in athletic shoes may lose their resilience or shock absorption, but they do not disappear when this capacity is lost. Rather, they show "wear and tear," which is an illustration of rule 2.
  4. All living things depend on the interaction of matter and energy in the process of photosynthesis; it is the primary mechanism whereby plants and microbes use the energy from the sun to make the basic building blocks of life.

LEARNING OBJECTIVES

Students

- define "sustainability" as the process of keeping the earth livable by preserving resources for future generations;
- use inductive reasoning to conceptualize the four rules (natural laws) that underpin Earth systems and sustainability;
- define in their own words and give examples of sustainability, matter, energy, photosynthesis, and the four rules (natural laws) underpinning sustainability.

PREP TIME: 20 MIN.
Gather materials for each demonstration.

CLASS TIME: 45-60 MIN.

background

THE NATURAL STEP (TNS)

The Natural Step (TNS) is an international organization founded in Sweden in 1989 by Dr. Karl-Henrik Robèrt, an oncologist who noticed a significant increase in childhood leukemia cases and witnessed firsthand the connection between human illness and toxins. TNS aims to promote a socially, ecologically, and economically sustainable society. With leading scientists, the organization is developing a planning method (called the Natural Step Framework) that individuals, businesses, and communities can use to develop their activities from the perspective of future sustainability: Simply put, do things today that will meet human needs today and tomorrow.

TNS helps companies implement this framework and encourages dialogue between company leaders and leaders in the field of sustainable development. What is "realistic" or "practical" is

Subject Areas:

Science

Skills:

Hypothesizing, investigating, inductive reasoning

Materials:

- Blackboard or whiteboard
- Students' science notebooks and writing instruments
- Scale
- Large chocolate chip cookie
- Glass and 1 ice cube
- Piece of plastic wrap
- Air freshener (*Note to teachers:* Because of asthma and allergies, consider this substitution: squeezing an orange or lemon rather than spraying air freshener.)
- Ingredients for baking cookies: flour, eggs, salt, butter, baking soda, chocolate chips, etc.
- Plant (or picture of one)
- Animal (or picture of one)

Key Vocabulary:

sustainability, matter, energy, photosynthesis, carbon dioxide, oxygen, glucose

THE NATURAL STEP (TNS) *(continued)*

never determined by profitability alone; there is always a vision of offering a product or service that is both commercially profitable and environmentally intelligent. Companies like IKEA, Nike, Interface, and Home Depot have all committed to sustainability and are using the TNS framework to make business decisions.

The TNS framework focuses on the causes of environmental problems rather than on their effects. Nature is the model. In nature

- matter and energy are neither created nor destroyed;
- matter and energy tend to disperse;
- there is no "away" – everything either becomes part of the life-decay-life cycle or becomes waste that can negatively affect the environment; and
- photosynthesis is the foundation of the life-decay-life cycle.

Using nature as a guide, TNS points out that sustainable systems are those in which nature's function and diversity are not

- subjected to increasing concentrations of substances taken from the earth;
- subjected to increasing concentrations of substances produced by society or
- impoverished by over-harvesting or other forms of ecosystem manipulation or physical destruction; and
- all resources are used to meet basic human needs worldwide.

LINKS:

http://www.thenaturalstep.org

http://www.detnaturligasteget.se/Tns/eng/introeng.html

FOR MORE INFORMATION: See **Glossary** (renewable resources, nonrenewable resources, matter, molecule, energy)

TEACHER TIP

This lesson provides concrete demonstrations of abstract concepts. One demo uses cookies. You may wish to "sweeten the learning" by sharing additional cookies with your students at the end of the lesson.

You can help students understand the lesson concepts by comparing the idea of sustainability to any sport with which your students are familiar. In a game, rules are rules: they are not up for debate. In fact, they actually define the game and let people play. In basketball, for example, there are five players on the court; in baseball, there are nine members on the field, and three strikes make an out. In the "game" of sustainability, the rules are based on commonly understood scientific principles about matter and energy (see concepts) that also function as a "given."

Note to teachers: *In science, we have theories that explain how we think things work. Though generally scientific principles are a "given," they can change based on increased understanding – for example, 40 years ago we believed the atom was the smallest component of matter; however today some of our ideas about matter have changed due to different understandings and technological developments. This, too, resembles what happens in sports: rules can be modified based on circumstances and/or increased understandings. For instance, the nature of a street pick-up game of basketball that started with five players may change if an additional player wants to join the game. And a few years ago, in golf, for example, the rules of a tournament were changed – after much debate – to allow a disabled player to ride a cart rather than walk the course like the other competitors.*

To win at a sport, players must know the objectives of the game and develop appropriate strategies for winning it. For example, a basketball team's goal is to put the ball in the basket more than the other team. The team practices certain plays and designates certain players to take an offensive or defensive role. A baseball team must score more runs to win. In the outfield they must know when and to whom to throw a ball to prevent the other team from scoring runs. To "win" the game of sustainability means to use what you know about the science of nature (natural laws) and Earth system conditions to develop appropriate strategies for working with, rather than against, them.

The "rules of the game" are the focus for Lesson 2. The "strategies," also referred to as "winning principles," are addressed in Lesson 3.

PROCEDURE

1. Review these concepts: system, open system, closed system, sustainability. (Consider using representative drawings from Lesson 1 – ask students to identify the type of system by the drawing and explain their reasoning. Given that the Earth is a closed system, what must humans do to keep it livable?)

   Definitions for sustainability vary. Here are two (see Glossary for additional information):

   - *keeping the earth livable by preserving resources for future generations* (Harvard Business Review)
   - *improving the prosperity and quality of life within the means of nature; using a resource so that it is not depleted or permanently damaged* (The Natural Step; A Child's Place in the Environment)

2. State that four rules (or laws of nature) govern life on Earth, and that they will discover these laws by drawing conclusions based on what happens in the following demonstrations. (Ensure students have a decent understanding of the terms "matter" and "energy" before doing these demonstrations.)

A. **Matter and energy cannot be created or destroyed.**

CHOCOLATE CHIP COOKIE DEMO

- Bring in a large chocolate chip cookie. Weigh the cookie and record the results.
- Now break the cookie into many pieces. Have students predict the weight of the pieces together: will it be more than, less than, or the same as the weight of the whole cookie? Ask them to explain.
- Weigh the pieces of cookie together. Record the results (it should weigh exactly the same because it consists of the same amount of matter). Keep these pieces for use in demonstrating the dispersal of matter and energy.

ICE CUBE/WATER DEMO

- Place an ice cube in a glass. Weigh the glass with the ice cube in it. Record the results.
- Ask students what will happen to the ice cube when it is left at room temperature (i.e., when heat energy of the room is applied).
- Have students predict the weight of the glass when the ice cube melts into water.
- Allow ample time for the ice cube to melt. Weigh the glass again. It should weigh the same because it still consists of the same amount of water. (***Note to teachers:*** Depending on the temperature of the room, water may evaporate and thus change the weight of the water, but this change will probably not show up on most scales. To be absolutely accurate, cover the glass to capture any water vapor; weigh the glass covered both times.)

DISCUSS

- These two experiments are both operating according to a natural law. Can anyone suggest what that law is? (Accept answers that resemble the following: matter can change form but cannot be destroyed – or created.)
- Write the rule on the board.
- Ask how that "rule" applies to this situation: a stick that burns. Does the stick disappear? No – energy (fire) transforms matter (stick) into matter (ashes, smoke) and energy (heat).
- Based on this rule of nature, ask students to explain what happens to the gas that fuels cars. Does it disappear (after all, we must keep filling up the tank!) or does it transform itself? How? (Accept answers that indicate an understanding that the gas [matter] gives the car energy to run [through ignition and combustion] and the combustion gives off matter in the form of exhaust fumes and "soot" deposited in the tailpipe – and byproducts of combustion are also deposited within the engine. Matter also transforms to energy in the form of heat (engine and the tailpipe are both too hot to touch).

B. Matter and energy tend to disperse.

COOKIE CRUMB DEMO

- Break the pieces of the cookie used in (A) into crumbs. Remind the class that the amount of matter in the cookie is still constant.
- If possible, take the cookie crumbs outside and toss them in the air, away from students, or drop them on the ground.
- Ask students to predict what will happen to the crumbs over time: will they stay together, or if not, where will they go? (animals could eat them, wind could blow them, they could be stepped on, etc.)

AIR FRESHENER (or LIME/ORANGE) DEMO

- Have students close their eyes and count out loud. Tell them to raise their hands, open their eyes, and write down the number they reached when they could first smell the scent that is dispersing throughout the room.
- Stand in one corner of the room and spray the air freshener (or cut open/squeeze the fruit). How long does it take to reach the other side?
- Discuss the idea of phase (or form) changes: liquid in the can changes to gas and travels through the room; the ice cube changed from solid to liquid.
- Re-emphasize that this is a transformation of matter (as in rule 1) and not a disappearance.

DISCUSS

- That odors of all kinds disperse.
- That these demonstrations have shown another rule of nature: that matter and energy don't stay in one place, but spread out.
- Write the rule on the board.

C. **The concentration and structure of matter determine how it can be used. It is that functionality that we use up. Stuff can't disappear but its functionality can.**

COOKIE INGREDIENTS COOKIE DEMO

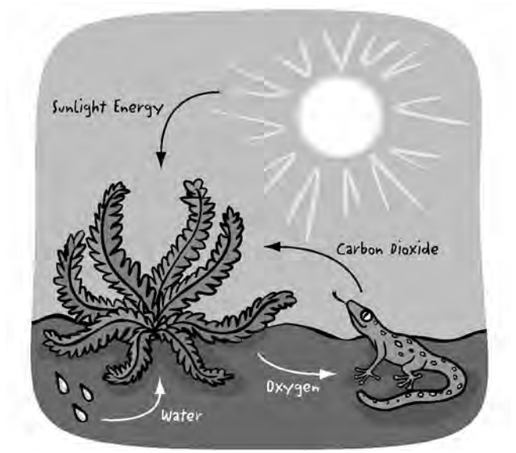
- Bring in ingredients for making cookies (flour, eggs, salt, butter, baking soda, chocolate chips, etc.). Ask students if they would like a spoonful of any of these ingredients. Why or why not? Which ingredients are desirable by themselves? Why?
- Offer them a cookie. Is the cookie more appealing than the collection of raw ingredients?
- Discuss the idea that the way the substances are combined, and the amounts of each, are what make it desirable (functional). Remind students of the water and ink demo (see Lesson 1) and how the ink changed the water's usefulness for drinking.

DISCUSS

- What items do students value? (trading cards, video games, etc.) Why are they valuable? What would happen to their value if they were taken apart, torn, or broken? (Value and functionality are destroyed.)
- Ask students: has any matter or energy been destroyed? (No.) Ask: What new idea have we learned, then, about matter? (Rule 3: The structure of matter determines if it is functional or valuable (how matter is put together or combined determines how it can be used). We don't use up matter (matter can't be created or destroyed) but we do use up matter's functionality.
- Write this rule on the board.

D. **All living things depend on the interaction of matter and energy in the process of photosynthesis; it is the primary mechanism where plants and microbes use the energy from the sun to make the basic building blocks of life.**

- Review the concept of photosynthesis with your students and restate in terms that are appropriate for your students' ages or comprehension levels (basic, average, advanced):
  Basic: when sunlight acts on plants to make food, and the plant gives off oxygen in the process.
  Average: the process used by green plants and other organisms to make carbohydrates from carbon dioxide and water, using light as an energy source. Most forms of photosynthesis release oxygen as a byproduct.
  Advanced: Use definition above and explain diagram below:



CO_2 + H_2O + ☀ → $C_6H_{12}O_6$ + O_2

Carbon dioxide — water — glucose — oxygen

1. Animals breathe out carbon dioxide and it enters the atmosphere. Plants take the carbon dioxide from the atmosphere.
2. Water is taken in by the plants from the atmosphere and the soil.
3. Sunlight breaks apart the molecular bonds of carbon dioxide and water.
4. These atoms reconfigure to form glucose (a simple sugar) that is used as energy (food) for the plant.
5. Oxygen is emitted into the atmosphere as a waste product of this process. Animals then inhale oxygen.

- Write the definition of photosynthesis on the board.
- *DEMO*
  Use the raw materials for cookies from the third demonstration and bring in a plant (or picture of one) and an animal (or picture, etc.). Ask students how each of these ingredients depends on photosynthesis. *Ultimately, everything depends on photosynthesis!*
- Explain that photosynthesis is an interaction between matter and energy. Recall the three natural laws already discussed. Explain that everything depends on photosynthesis. It is the process that keeps "order" and balance on the earth when matter transforms to energy. This is the fourth rule for the "game" of sustainability.

Evaluation/Wrap-Up:

Ask students to define in their own words and to give examples of the following concepts (have them imagine they are explaining the concepts to a younger student). Students may work in pairs or small groups and write their responses in their science notebooks or journals.

- sustainability
- matter
- energy
- photosynthesis
- each of the four system conditions for sustainability

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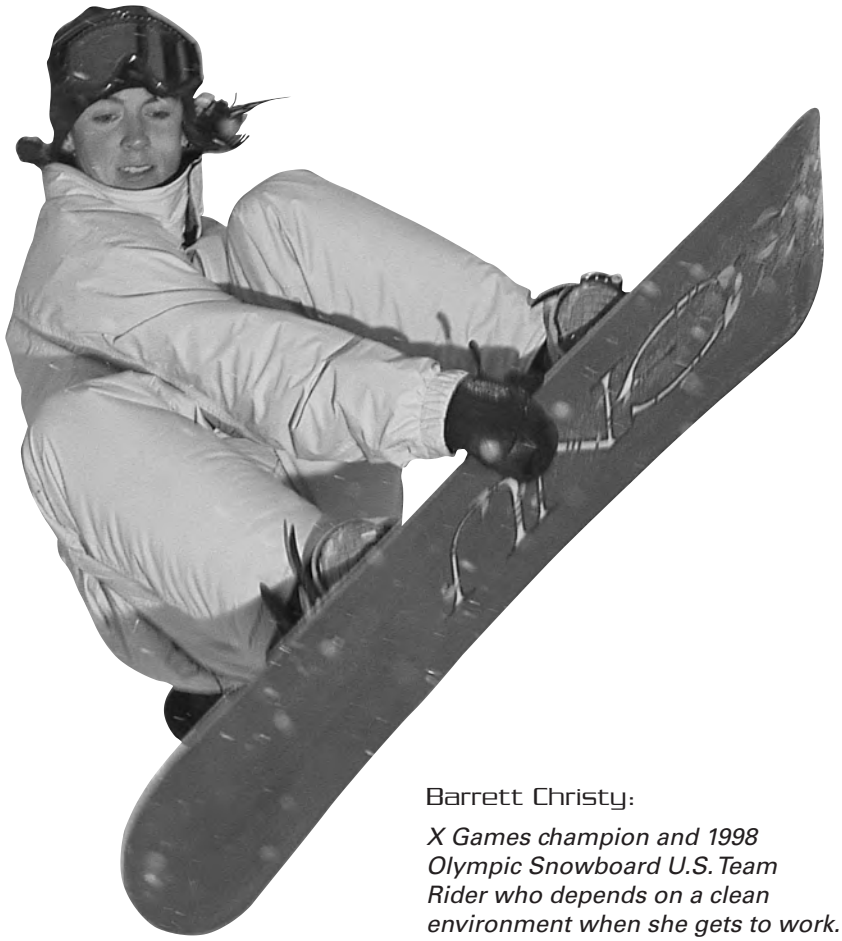
Enrichment

Ask students to choose a product and focus on one resource (a tree, a stream, petroleum, iron ore, etc.) used to make that product. Have students show, in drawings or words, how each natural law may have impacted the product, or how the product manufacturing process was in keeping with, or against, natural laws.



Barrett Christy:

X Games champion and 1998 Olympic Snowboard U.S. Team Rider who depends on a clean environment when she gets to work.